REMARKS

Claims 18-22 are all the claims presently pending in the application. Claims 18-22 have been amended to more clearly define the invention. Claims 18-22 are independent.

Entry of this §1.116 Amendment is proper. Since the amendments above narrow the issues for appeal and since such features and their distinctions over the prior art of record were discussed earlier, such amendments do not raise a new issue requiring a further search and/or consideration by the Examiner. As such, entry of this Amendment is believed proper and Applicant earnestly solicits entry. No new matter has been added.

These amendments are made only to more particularly point out the invention for the Examiner and not for narrowing the scope of the claims or for any reason related to a statutory requirement for patentability.

Applicant also notes that, notwithstanding any claim amendments herein or later during prosecution, Applicant's intent is to encompass equivalents of all claim elements.

Claims 18-22 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Chang (EP 0947325), in view of Sakai (U.S. Patent No. 5,933,168) and Ebi, et al. (U.S. Patent No. 4,364,057).

This rejection is respectfully traversed in the following discussion.

I. THE CLAIMED INVENTION

The claimed invention is directed to a method for driving an ink jet recording head. The method includes applying a driving voltage to an electro-mechanical converter to deform the electro-mechanical converter to thereby change a pressure in the pressure generating

chamber filled with ink, thus ejecting ink droplets through a nozzle in communication with the pressure generating chamber.

The driving voltage includes a first voltage changing process, a second voltage changing process and a third voltage changing process. The first voltage changing process is for applying a voltage in a direction that increases a volume of the pressure generating chamber. The second voltage changing process is for applying a voltage in a direction that reduces the volume of the pressure generating chamber. The third voltage changing process is for applying a voltage in a direction that increases the volume of the pressure generating chamber again.

The voltage changing times t_2 and t_3 during the second and third voltage changing processes are set so as to have such lengths as shown below, relative to a resonance frequency T_c of a pressure wave generated in the pressure generating chamber: $0 < t_2 < T_c/2$; and $0 < t_3 < T_c/2$. Lastly, the method further includes providing a nozzle with an about 20 to less than 30 μm opening diameter to eject said ink droplets in a size of about 5 to about 25 μm size.

This configuration provides a method for driving an ink jet recording head having a nozzle opening of about 20 to less than 30 μm which enables fine ink droplets having a smaller size (for example, about 5 to 25 μm) from a nozzle to be stably ejected even at a high frequency. The pressure wave generated by ejecting a fine ink droplet is most efficiently restrained from reverberating by setting the time interval between a start time of the second voltage changing process and a start time of a fourth voltage changing process, equal to or shorter than half of the resonance frequency Tc of the pressure wave in the pressure generating chamber. This is because the pressure wave will have a phase opposite to that of

the pressure wave generated by the second voltage changing process and this will efficiently cancel the latter pressure wave.

In summary, while meniscus control may be known, an optimal driving voltage waveform for smaller volume of ink drops (i.e. approximately 10^{-12} liters) in meniscus control did not exist until the present invention. The present invention utilizes pressure waves generated at nodes of the driving voltage waveform to eject a smaller volume ink drop in accordance with optimal rising/falling times of the driving voltage waveform.

An exemplary embodiment of the present invention enables small drops by providing a rising time of a second voltage changing process to be less than Tc/2, adding a third voltage changing process, the falling time of the third voltage changing process being less than Tc/2, and the start time of the third voltage changing process being the end of the second voltage changing process.

Further, by providing a nozzle opening of about 20 to less than 30 μm, an exemplary embodiment of the present invention is capable of ejecting smaller ink drops without causing blocking at the nozzle, and enables fine ink drops to be stably ejected even at high frequency.

II. THE PRIOR ART REJECTION

Regarding the rejection of claims 18-22, the Examiner alleges that the Sakai reference would have been combined with the Chang et al. reference and further that the Ebi et al. reference would have been combined with the Chang et al. and Sakai references to form the claimed invention. Applicant submits, however, that these references would not have been combined and even if combined, the combination would not teach or suggest each and every element of the claimed invention.

Applicant submits that these references would not have been combined as alleged by the Examiner. Indeed, the references are directed to completely different matters and problems.

Specifically, the Chang et al. reference is directed to reducing the size (col. 2, lines 1-2) of an ink drop which is produced by a driving method for forming ink drops which include a contraction step to eject an ink drop followed by an expansion step to absorb the tail of the ink drop (col. 1, line 54 - col. 2, line 1) by ensuring that the velocity of the trailing end of the ejected ink drop is substantially zero at a position near the nozzle orifice (col. 2, lines 45-51).

In contrast, the Sakai reference is specifically directed to stably providing an ink drop with a size which is smaller than the size of the nozzle opening (col. 2, lines 28-33) without suffering the problems experienced by previous systems (col. 2, lines 9-26). These previous systems included nozzle openings of 51 to 56 micrometers and could produce ink drops at a size of between 10 to 15 micrometers. However, these previous systems suffered from gaps between drops (col. 2, lines 12-15), a curve to the path of the ink drop which therefore won't follow a predetermined path (col. 2, lines 14-21), and the temperature dependency of this effect (col. 2, lines 21-26).

Therefore, one of ordinary skill in the art would not have been motivated to modify the Chang et al. reference based upon the teachings of the Sakai reference because the Chang et al. reference is concerned with ensuring that the velocity of the trailing end of the ejected ink is substantially zero at the nozzle orifice where the Sakai reference is concerned with stably providing an ink drop with a size which is smaller than the nozzle opening. Thus, the references would not have been combined, absent hindsight.

Further, in contrast to the Chang et al. and Sakai references, the Ebi et al. reference is specifically directed to solving the problem of inclined lines of dots being formed because the paper continues to move in a direction which is perpendicular to the motion of an electrostatic ink jet print head (col. 1, lines 19 - 38). The Ebi et al. reference allegedly solves this problem by providing the electrostatic ink jet print head with an ink-drop-landing-position control electrode.

Since neither of the Chang et al. and Sakai references disclose an electrostatic ink jet print head which ejects ink drops on the order of 100 micrometers (col. 3, lines 9-10) and which alters the path of such an ink drop by applying a charge to the ink drop (col. 2, lines 61 - 65) and by passing between deflection plates (col. 2, line 67 - col. 2, line 4), one of ordinary skill in the art would not have been motivated to modify the teachings of the Chang et al. and Sakai references based upon the disclosure of the Ebi et al. reference. Thus, the references would not have been combined, absent hindsight.

Further, Applicant submits that the Examiner can point to no motivation or suggestion in the references to urge the combination as alleged by the Examiner.

The Examiner alleges that it would have been obvious to modify the Chang et al. reference based upon the teachings of the Sakai reference to provide a nozzle with an aperture of 32 micrometers "to avoid the disadvantages due to the size of the reduced size ink droplet created is so small compared with the size of the nozzle opening in order to stably eject ink droplets with a required amount of kinetic energy" and cites column 2, lines 10-26 of the Sakai reference.

However, contrary to the Examiner's allegation, column 2, lines 10-26 of the Sakai reference does not provide any motivation to provide a nozzle opening of 32 micrometers.

Rather, this section of the Sakai reference details the disadvantages (col. 2, line 10) of a system which expands the pressure producing chamber at a speed higher than during the ink charging operation so that the meniscus is rapidly drawn toward the pressure producing chamber and so that part of the ink separates from the meniscus (col. 1, lines 57 - 66). The Sakai reference provides a specific example of such a system which has a nozzle opening of 51 to 56 micrometers. Column 2, lines 10-26 then list all of the disadvantages of such a system.

Therefore, contrary to the Examiner's allegation, column 2, lines 10-26 do not provide any motivation at all to do anything other than to search for an alternative to the system described at col. 1, line 45 through col. 2, line 9). Thus, this section does not provide any motivation at all to provide a nozzle opening of 32 micrometers.

The Examiner cites column 6, line 42 for the disclosure of a nozzle opening of 32 micrometers. However, this disclosure is merely exemplary and does not provide any motivation to modify anything, let alone to modify the disclosure of the Chang et al. reference based upon the Sakai reference.

Additionally, contrary to the Examiner's allegation, one of ordinary skill in the art would not have been motivated at the time of the invention to modify the system disclosed by the Chang et al. reference with a nozzle aperture of 30 micrometers. The Examiner alleges that one of ordinary skill in the art would have been motivated to modify the system disclosed by the Chang et al. reference with the disclosure of the Ebi et al. reference "to generate the ink drops with an extremely fine diameter whereby the density of ink dots can be increased and consequently the resolution can be improved" and cites column 3, lines 15-21.

Contrary to this allegation, column 3, lines 15-48 of the Ebi et al. reference explains that while smaller nozzle diameters have been proposed (smaller than 100 micrometers (col. 3, lines 9-11)) to reduce the size of the ink drops as much as possible (col. 3, lines 15-22) a problem arises if the nozzle becomes too small. The Ebi et al. reference explains that while a nozzle diameter of 50 micrometers has been used (col. 3, lines 22-23), such small particles do not have enough kinetic energy to overcome the aerodynamic and electrostatic disturbances while in flight and lands unpredictable and will distort the image (col. 3, lines 23-34).

The Ebi et al. reference then provides specific examples of how a nozzle size which is too small will produce ink drops that do not have enough kinetic energy. The Examiner's favored citation is the reference to a nozzle diameter of 30 micrometers which appears at col. 3, line 36 of the Ebi et al. reference. However, this is given as an example of a nozzle diameter which is too small in comparison to a nozzle size of 50 micrometers (col. 3, line 42). In other words, the Ebi et al. reference actually teaches away from providing a nozzle diameter which is as small as 30 micrometers because such an ink drop would not have enough kinetic energy to produce undistorted images. Therefore, contrary to the Examiner's allegation, the Ebi et al. reference does not provide any motivation at all to modify the teachings of the Chang et al. reference with a nozzle having a smaller diameter because the Ebi et al. reference teaches away from providing a nozzle diameter which is any smaller diameter than 50 micrometers.

Further, as explained above, one of ordinary skill in the art would not have been motivated to modify anything which is disclosed by the Chang et al. reference with the disclosure of the Ebi et al. reference because the Ebi et al. reference is only relevant to electrostatic ink jet printers. Clearly, the Chang et al. reference does not disclose an

electrostatic ink jet printer. Therefore, one of ordinary skill in the art would not have been motivated to modify the teachings of the Chang et al. reference with the disclosure of the Ebi et al. reference because the Chang et al. reference has absolutely nothing to do with electrostatic ink jet printers.

Even assuming arguendo that one of ordinary skill in the art would have been motivated to combine these references, the combination would not teach or suggest each and every element of the claimed invention. None of the applied references teach or suggest providing a nozzle with an about 20 to less than 30 μm opening. As noted above, the claimed invention provides a method for driving an ink jet recording head having a nozzle opening of about 20 to less than 30 μm which enables fine ink droplets having a smaller size (for example, about 5 to 25 μm) from a nozzle to be stably ejected even at a high frequency.

Clearly, these novel features are not taught or suggested by the applied references.

The driving waveform disclosed by the Chang et al. reference is not based upon meniscus control. Meniscus control requires the first voltage changing process to pull inwardly. In stark contrast, the present invention introduces the waveform for meniscus control. The Chang et al. reference does not teach or suggest generating pressure waves at the nodes of the driving waveform.

Further, the voltage changing time of the second voltage changing process is not defined, taught or suggested in the Chang et al. reference. In contrast, the voltage changing time of the second voltage changing process plays an important role in the present invention.

Further, even if the Chang et al. reference discloses voltage changing times with a resonance frequency Tc, the Chang et al. reference does not explain why these times (if any) are

defined relative to Tc. Therefore, the Chang et al. reference does not provide any foundation for defining voltage changing times relative to Tc.

Additionally, even if the Sakai reference discloses meniscus control, Sakai does not teach or suggest any process which might correspond to the third voltage changing process in accordance with the present invention.

The object of the Sakai reference is to excite two vibration systems in a pressure generating chamber to diminish the phase difference and to enhance ink-ejection efficiency. The Sakai reference is not at all concerned with reliably and stably ejecting ink drops having a small volume.

The Ebi et al. reference discloses an electrostatic ink jet apparatus which is completely different from the ink ejection of the present invention. Even if the Ebi et al. reference states that the reduction of the nozzle diameter is efficient for making ink drops smaller, this statement is merely a widely accepted generalization of ink jet techniques. However, as discovered by the present inventors, there are nozzle diameters which are optimal for a particular control method. The present invention defines the optimal nozzle diameter with the recited control method to be about 20 to less than 30 μm.

Therefore, the Examiner is respectfully requested to withdraw this rejection of claims 18-22.

III. FORMAL MATTERS AND CONCLUSION

In view of the foregoing amendments and remarks, Applicant respectfully submits that claims 18-22, all the claims presently pending in the Application, are patentably distinct

over the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

Should the Examiner find the Application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary in a telephonic or personal interview.

The Commissioner is hereby authorized to charge any deficiency in fees or to credit any overpayment in fees to Attorney's Deposit Account No. 50-0481.

Respectfully Submitted,

Date: 6/5/03

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